ADHESION AND FRACTURE OF BIOLOGICAL AND BIO-INSPIRED SOFT TWO-DIMENSIONAL STRUCTURES

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Today, the chemical adhesives and sealant market is growing thanks to its versatility in the industry. Adhesive tapes and glues are now used in aeronautics, robotics, and other innovative fields. However, several flaws afflict these products: they are non-recyclable, disposable tools, and their manufacturing process often generates highly toxic waste, which can become pollutants in both waste waters and production gases. This anthropological approach is in contrast to the one commonly used by animals and plants. Thanks to particular geometrical and mechanical properties, it is possible to find strong, reversible, self-cleaning biological adhesives which exploit chemical and physical phenomena to sustain extreme loads. Adhesion, friction, sliding, stress and fracture propagations are all involved in the mechanical response of these biological adhesives, thus requiring the analysis of complex interactions between the material, the contact interface and the substrate.

In this work, we present a numerical model which was developed to study the mechanical behaviour of biological and bio-inspired structures during delamination and fracture progression. The model, based on one-dimensional truss elements, can represent two-dimensional soft structures thanks to Lattice Spring Models and Discrete Cohesive Zone Models. The in-house developed code uses C++ classes to define the mathematical formulation of the contact, thus supporting a variety of contact formulations, enabling the study of frictional and sliding behaviours. Results have been validated by comparing the obtained simulations to continuum mechanics and adhesion theories[1,2]. We were then able to simulate how structural aspects influence the delamination and fracture of biological adhesives, i.e. spider-silk anchorages. We show how, by exploiting the mechanical properties of the different types of silk, spiders can build structures which have unique responses to pulling forces, achieving high pull-off forces and deformability for high pulling angles, in contrast to what is predicted by single peeling theories.

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